# DESERTEC - The concept design for the supply Europe with electricity from large distances

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**Abstract** –The major criteria for large scale projects are development effort, development timescale and time plane. The secondary criteria are technology risk and organization impact. The aim of this paper is to analyze the future perspectives of the new technologies of Concentrated Solar Power systems (CSP) systems. The CSP technologies like the "Central Receiver and Parabolic Trough" can be used as a key instrument for secure and affordable Energy Supply in DESERTEC project.

**Keywords** – DESERTEC, Concentrated Solar Power systems, Efficiency Technology, Parabolic Trough, Central Receiver

## Introduction

The population growth of earth increases strongly. Since 1800 the world's population has grown from approximately 1 billion human beings to more than 6.8 billions and according to UNO[1], this figure will continue increasing up to more than 9 billions in the next 50 years. This rapid growing world population will increase the global demand for primary power. It will almost be double by the year 2060.

Today the world is depending on limited and non-renewable sources of fossil fuels (oil, coal, gas) and uranium (nuclear energy). On the one side, fossil fuels are available on earth in limited quantity and will vanish within fifty/sixty years from now.[2] In addition, these resources are not environmental friendly, as they produce around 21.3 billion tons (21.3 giga tons) of carbon dioxide (CO2) per year.[3] The atmospheric CO2-concentration increases rapidly due to the combustion of fossil energy sources. This emission mainly contributes for global warming and the fact, that the pollution is added year by year, the problem of changing the sources should not be solved only at the possible maximum end of the availability of fossil fuels. On the other side the nuclear energy has to deal with the waste.

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[1] United Nations Organization, Department of Economic and Social Affairs, Population Division: http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

[2] http://www.conserve-energy-future.com/

[3] US Department of Energy on greenhouse gases: http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html.

Although the output of waste is relatively small, it releases harmful radiation as it decays and there is no method to get rid of the radioactivity of the waste or speed up the rate of decay.

The emerging and strongly escalating demand for energy will have to be increasingly met in a sustainable and environmentally friendly way. Therefore the importance of renewable energy sources has been perceived higher in the last years.

The use of renewable energy increased during the last years. In 2009, about 3% of global electricity came from renewable energy, which generated worldwide approximately 305 Giga watts (GW). From these roughly 160 GW were generated by Wind energy, 60 GW by Small Hydro, 50 GW by Biomass, 10 GW by Geothermal energy and 25 GW by Solar energy. Whereas the worldwide area for Wind technologies becomes saturated, the development of solar energy is growing substantially. Concentrated Solar Power, especially technologies like parabolic trough and central receiver are considered as a key to secure and affordable energy supply.

**The DESERTEC Project**

By far the largest renewable energy source is the sun. It exists for about 4.5 billion years and will exist for about another 4 billion years. The amount of energy that the earth's surface can reach corresponds to the 10,000 times the world primary energy demand.[4]

The solar energy available in deserts is more than 700 times the present global primary energy consumption. This is far more than needed to replace fossil fuels. The deserts receive in more than 6 hours and energy from the sun than humanity consumes in a year.[5]

According to site selection studies by German Aerospace Center (DLR) using satellite data the deserts in the Middle East and North Africa (MENA) region would allow the production of electricity of 630,000 TWh/year, about 40 times the present world electricity demand.[6]

The DESERTEC is a concept proposed by the DESERTEC Foundation to make use of solar and wind energy from the Sahara desert. The objective of the project is to supply 15% of the European electricity demand by 2050 from RES sources in the MENA region through High-voltage direct current (HVDC) lines. The expected investment of the project is roughly 400 billion euro over 40 years.

Under the DESERTEC proposal, Concentrated Solar Power systems (CSP) and wind parks would be located on 17,000 km² in the Sahara Desert. The potential of electricity generation from solar energy in EU-MENA is 10-250 GWh/km²y. That implies 630.000 TWh/y.

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[4] DESERTEC foundation: http://www.desertec.org/de/

[5] German Aeroespace Center: http://www.dlr.de/

[6] Dr. Gerhard Knies, "Global Energy and Climate Security through Solar Power from Deserts" , Trans-Mediterranean Renewable Energy Cooperation TREC.July 2007.

Table 1 illustrates the potential of electricity generation for renewable energy in EU-MENA.[7]

| Renewable Energy | GWh/km²y | TWh/y |
|---|---|---|
| Biomass | 0-1 | 1.350 |
| Geothermal | 0-1 | 1.100 |
| Small Hydro | 0-50 | 1.350 |
| Wind energy | 5-50 | 1.950 |
| Solar energy | 10-250 | 630.000 |

**Table 1: Potential for Renewable Energy in EU-MENA**

The current electricity consumption of the world is 17.000 TWh/y, of Europe-25 3.200TWh/y and of MENA 600 TWh/y.

**Concentrated Solar Power systems**

Concentrated Solar Power (CSP) comprises a series of technologies devised for the transformation of the direct component of solar radiation into high temperature thermal energy by means of concentrators based on mirrors or lenses.

An advantage of the CSP plants is that the energy can be easily stored large amounts of thermal energy with minimal losses, thus they can provide energy on demand during day and night. CSP plants contribute to stabilize the electricity grid by compensating fluctuations of renewable energy sources if they are part of the same network.

Concentrating thermal power is the main technology proposed for a cooperation to produce electricity and desalinated water in the arid regions of North Africa and Southern Europe by the Trans-Mediterranean Renewable Energy Cooperation DESERTEC.

Concentrated Solar Power has developed technology in two variants, linear concentrator and point concentrator.

**Linear Concentrators – Parabolic Trough**

In parabolic trough power plants long trough shaped parabolic mirrors, usually coated silver or polished aluminum, concentrate Direct Normal Irradiation (DNI) to heat a medium in a pipe with thermal fluid running in the line of focus where the absorber is located. The trough is usually aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day.

[7] DESERTEC foundation: http://www.desertec.org/de/

The heat transfer fluid is then used to heat steam in a standard turbine generator. The process is economical and, for heating the pipe, thermal efficiency ranges from 60-80%. The overall efficiency from collector to grid, i.e. Electrical Output Power/Total Impinging Solar Power is about 15%, similar to Photovoltaic (PV) Cells but less than Stirling dish concentrators.[8]

This technology is actually used in the Andasol complex located near Guadix in Andalusia, Spain.[9]

### Linear Concentrators – Linear Fresnel

Linear Fresnel technology is an advanced variant of parabolic trough. It has the advantage that flat mirrors can be used which are much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used. Concentrating Linear Fresnel reflector can come in large plants or more compact plants.[10]

Table 2 illustrates how a parabolic and lineal fresel collector focuses sunlight onto its focal point.[11]

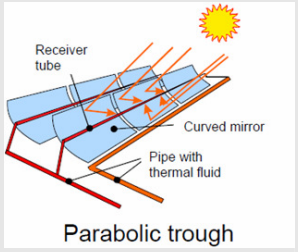
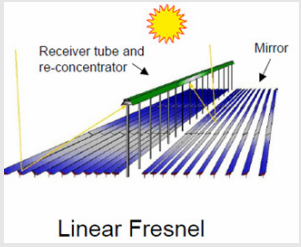
| **Linear Concentrators** |  |  |
|---|---|---|
| Concentration | 70-80 | 25-100 |
| Temperature | ~500°C | ~500°C |
| Unit size | 1-250 MW | 1-200 MW |
| Efficiency | 10-15% | 9-15% |

**Table 2: Comparison of Linear Concentrators – Parabolic Trough and Lineal Fresel[12]**

### Point Concentrators – Dish Stirling

The Dish Stirling consists of a single parabolic reflector which concentrates light at the focal point of the reflector, which tracks the sun along two axes. Of all the CSP technologies, parabolic dish systems are the most efficient. The 50 kW Big Dish in Canberra, Australia is an example of this technology. The Stirling solar dish combines a parabolic concentrating dish with a Stirling heat engine which drives an electric generator. The term "Stirling" refers to the fact that the device operates on a simple heat-engine principle. Stirling solar energy production is more efficient than photovoltaic cells and the

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[8] Patel., Mukund. "Wind and solar power systems". London New York Washington, D.C.: 1999, ISBN 0-8493-1605-7.

[9] http://www.estelasolar.eu/ ESTELA (European Solar Thermal Electricity Association), "Solar Power from the Sun" Belt Brussels, June 2009.

[10] Idem

[11] DESERTEC foundation: http://www.desertec.org/de/

[12] idem

technology has a longer lifetime.[13]/[14] This technology is ideal for rural areas and can be produced and repaired very easily.

### Point Concentrators – Central Receiver

Consists of an array of dual-axis tracking reflectors (heliostats) that concentrate light on a central receiver at the top of a tower. The receiver contains a working fluid to absorb the heat, and can be seawater. The working fluid in the receiver is heated to 500-1000 °C and then used as a heat source to generate power or to store energy. One advantage of the central receiver technology is that it provides the possibility of operating with high steam conditions, leading to high thermal cycle efficiencies, thus having high efficiency. Fig. 2 illustrates the point concentrator cycle and the differences in efficiency and concentration.[15]/[16]

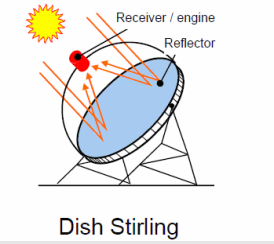
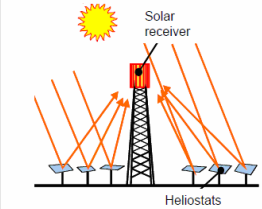
| **Point Concentrators** |  Dish Stirling |  Central receiver |
|---|---|---|
| Concentration | >1.000 | 300-1.000 |
| Temperature | ~1.200°C | ~1.200°C |
| Unit size | 0,01-0,04 MW | 1-200 MW |
| Efficiency | 18-25% | 14-17% |

**Table 3: Comparison of Point Concentrators – Dish Stirling and Central Receiver[17]**

### Conclusion

The current energy system is susceptible to being modified to achieve greater efficiency and to sharply decrease CO2 emissions. Spain is the world leader in concentrated solar power technology, with more than 50 projects underway. The DESERTEC scheme has been described as being part of an overall intention to create a new carbon-free network linking Europe, the Middle East and North Africa.[18] The CSP technologies for producing energy from solar radiation are very promising for the substantial

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[13] http://www.estelasolar.eu/ ESTELA (European Solar Thermal Electricity Association), "Solar Power from the Sun" Belt Brussels, June 2009.

[14] http://oilprice.com/Alternative-Energy/Solar-Energy/The-Potential-and-Future-of-Concentrated-Solar-Power.html

[15] http://www.estelasolar.eu/ ESTELA (European Solar Thermal Electricity Association), "Solar Power from the Sun" Belt Brussels, June 2009.

[16] J.C. Martín, "Solar Tres: First commercial molten salt central receiver plant 17 MW, 15h storage, 6500 h/y, SENER Ingeniería y Sistemas, S.A.", NREL CSP Technology Workshop. Denver, March 2007.

[17] DESERTEC foundation: http://www.desertec.org/de/

[18] Prof. C. Rhodes, "The Potential and Future of Concentrated Solar Power", October 2010 in: http://oilprice.com/Alternative-Energy/Solar-Energy/The-Potential-and-Future-of-Concentrated-Solar-Power.html

modification of the energy system. There is a long way to go in all the four technologies and their application to electricity generation especially in the improvement of efficiency, cost reduction, development of storage, design of the absorber; all these aspects improve the integration of CSP plants into the power systems. Nevertheless a deep comparison of the technology will help to analyze the potential of new CSP technologies, thus will help to reduce cost and increase efficiency for the future solar energy production. One alternative is the central receiver, which has more efficiency, good availability for dispatchable power and least-cost KWh produced.